

Near Infrared Angular diameters of a few AGB variables by Lunar Occultations

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ABSTRACT

The uniform disk (UD) angular diameter measurements of two oxygen-rich Mira variables (AW Aur and BS Aur) and three semiregular (SRb) variables (GP Tau, RS Cap, RT Cap), in near Infrared K -band ($2.2\ \mu\text{m}$) by lunar occultation observations are reported. UD angular diameters of the two Miras and one SRV are first time measurements. In addition a method of predicting angular diameters from (V-K) colour is discussed and applied to the five sources. The effect of mass-loss enhancing measured K -band diameters is examined for Miras using ($K - [12]$) colour excess as an index. In our sample the measured angular diameter of one of the Miras (BS Aur) is found enhanced by nearly 40% compared to its expected value, possibly due to mass loss effects leading to formation of a circumstellar shell.

Key words: stars: AGB and post-AGB – stars: variables: general – techniques: high angular resolution – occultations – infrared: stars

1 INTRODUCTION

Asymptotic giant branch (AGB) stars are highly evolved cool stars in the last stages of their stellar evolution before turning into planetary nebulae. The high mass loss rates ($10^{-7} - 10^{-6}\ M_{\odot}\text{yr}^{-1}$) and relatively low surface temperatures of these stars provide a habitable zone for several molecules like TiO , VO , H_2O and CO in their extended atmospheres. A very common characteristic of AGB stars is the long period variability of their radiative output, mainly, due to pulsation of their atmospheres though episodic ejection of dust can also contribute to the variability (Lattanzio & Wood, 2003). Traditionally AGB stars have been classified according to their visual variability amplitude in magnitude as (1) classical Mira variables (visual amplitude > 2.5), clearly defined periodicity in the range 100-1000 days, (2) Semi-regular variables (SRV): SRa - visual amplitude < 2.5 and periods in the range 35-1200 days; SRb - visual amplitude < 2.5 with poorly defined periods, (3) Irregular variables with small amplitude and no definite periods. In addition there is also a class of Super-giant semi-regular variables (SRc). Micro-lensing surveys such as *MACHO* (Alcock et al., 1995), *EROS* (Aubourg et al., 1993) and *OGLE* (Udalski et al., 1993) during the last 15 years have produced many high quality light curves of the AGB stars

upto V -mag ~ 20 which have discerned distinct periodicities in objects hitherto classified as irregular variables.

A recent important class of AGB variables too faint to be found in GCVS (General Catalog of Variable Stars; Samus et al., 2009) consist of dust enshrouded infrared variables, found in Infrared surveys, which pulsate with larger amplitude in K -band ($2.2\ \mu\text{m}$) (K -amp ~ 3) and longer period (≥ 600 days) than optical Mira Variables (Whitelock et al., 1994; Wood, Habing & McGregor, 1998). The dust enshrouded IR variables are considered to be in a more advanced state of evolution than classical Miras.

High angular measurements of angular sizes of Mira variables at different phases of their pulsation cycle provide an important direct means of understanding their atmospheric extension and pulsation properties. However, large opacities due to absorption by molecular species in their atmospheres mask the dominant continuum radiation from the photosphere. Consequently, photospheric angular size measurements are affected differently in different filter bands which has been known for sometime (Haniff, Scholz & Tuthill, 1995). In recent years there have been many high quality measurements of Mira variables at IR wavelengths but measurements of SRVs are relatively few. Mennesson et al. (2002) found L' -band diameters of several oxygen rich Miras were much larger (25% to 100%) than those measured in the broad K -band and ascribed it to a wavelength dependent transparency of an optically thin gaseous shell around the star. In a multi-epoch interferometric study of two Mira variables spread over several pulsation cycles, Thompson,

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[†] This file has been amended to highlight the proper use of $\LaTeX 2_{\epsilon}$ code with the class file.

Table 1. Observational details of *Lunar Occultation* events.

Source	JD Obs. 2450000+	Phot. Phase [†]	Lunar Phase (days)	Alt. (°)	Detector used	Samp. time (millisec)	S/N	V_{comp}^{\ddagger} (m/ms)	PA [§] (°)	CA [‡] (°)
AW Aur	3802.082	0.95	7.6	85.5	InSb Photometer	1.00	14	0.616	71.3	16.4
BS Aur	3775.306	0.83	10.2	45.1	InSb Photometer	1.00	20	0.807	87.0	13.9
GP Tau	2710.251	0.43	8.6	29.5	InSb Photometer	2.00	19	0.486	148.1	55.2
RS Cap	4804.023	0.43	5.8	36.0	HgCdTe subarray	7.29	39	0.339	-5.7	58.2
RT Cap	4802.908	0.72	4.7	36.9	HgCdTe subarray	8.75	48	0.516	91.0	27.5

[†] Photometric phase is derived for the epoch of our observation from GCVS or ASAS catalogues. It varies from 0 to 1 with 0.5 signifying minimum light.

[‡] V_{comp} refers to the predicted velocity component of the moon in the direction of occultation.

[§] PA is the position angle of the point of occultation on the lunar limb measured from North to East.

[‡] CA is the contact angle between the direction of lunar velocity and the direction of occultation.

Creech-Eakman & van Belle (2002) report variations in narrow band angular sizes within the K -band ($2.0 - 2.4 \mu\text{m}$) and attribute them to molecular absorptions. Perrin et al. (2004) observed several Miras in the narrow bands around $2.2 \mu\text{m}$ and found systemically larger diameters in bands contaminated by water vapour or CO. Millan-Gabet et al. (2005) report from simultaneous measurements in J , H and K' -bands of 23 Miras, a systematic increase of angular size with wavelength (25%) from J to H to K' . Mondal & Chandrasekhar (2005) find a 20% increase in their K -band Lunar Occultation (LO) measurement of one Mira (U Ari) compared to a reported H -band measurement at the same phase. These authors also reported that two SR variables do not show any phase variation in their K and L' angular diameters. In a detailed 3 telescope interferometric study in the H -band Ragland et al. (2006) find that almost all Miras show an asymmetry in their brightness distribution and attribute it to the formation of an inhomogeneous translucent molecular screen located at about 1.5 to 2.5 stellar radii. Eisner et al. (2007) using higher spectral resolution interferometric observations of a Mira (R Vir) find the measured radius of emission varies substantially from 2.0 to $2.4 \mu\text{m}$. They infer that most of the molecular opacity arises predominantly due to H_2O at about twice the stellar photospheric radius. Propagating shocks associated with Mira pulsation provide a mechanism for lifting the molecular layer to the observed location. Woodruff et al. (2009) in a spectro-interferometric study of 3 Miras from 1.1 to $3.8 \mu\text{m}$ report strong size variations with wavelength probing zones of H_2O , CO , OH and dust. The variation in UD angular diameters by a factor of two from 1.0 to $3.0 \mu\text{m}$ consolidates the picture of a Mira atmosphere consisting of molecular shells and time dependent densities and temperatures.

In this paper we present high angular resolution measurements in the broad K -band using the Lunar Occultation technique of two oxygen rich Miras and three semiregular variables. Uniform Disk (UD) angular diameters are reported. For the two Miras and one SRV (GP Tau) UD diameters are reported for the first time.

2 OBSERVATIONS AND DATA ANALYSIS

The LO observations of all but one of these sources were carried out in the near-Infrared broad- K -band ($2.2 \mu\text{m}/0.4$

μm). The bright source RS Cap was observed in narrow CO -band filter ($2.37 \mu\text{m}/0.1 \mu\text{m}$) to avoid saturation effects. The details of the observations are listed in Table.1. The 1.2 m telescope of Mt Abu IR-observatory (lat: $24^\circ 39' 10'' \text{ N}$, Long: $72^\circ 46' 47'' \text{ E}$, Alt: 1680 m) was used for observations with two different IR detector systems. All are disappearance events at lunar phase measured in days after new moon as listed in Table.1. Three sources (AW Aur, BS Aur and GP Tau) were observed with an older system using a single element InSb detector with an effective field of view about 10 arcsec in the sky. The details of this system can be found in Chandrasekhar (2005). The other two sources were recorded using the $10 \times 10 \text{ pixel}$ ($5'' \times 5''$) subarray of a $256 \times 256 \text{ pixel}$ Mercury Cadmium Telluride (MCT) detector array of the NICMOS IR-camera. Details of the subarray mode of operation for lunar occultations and analysis are extensively discussed in a recent paper (Chandrasekhar and Baug, 2010). Typically an observing run in the subarray mode consists of initiating the data acquisition procedure for recording 4800 sub frames about 20 seconds before the predicted time of the event. About 15 seconds after the predicted event time the telescope is rapidly switched to nearby sky to record sky frames. Sky subtracted sub-array frames are used to derive the light curve.

The light curve is carefully analysed to extract the uniform disk (UD) angular diameter of the stellar source using the method of non-linear least squares (NLS) first enunciated by Nather and McCants (1970) and extensively modified by us. NLS involves five parameters, namely, geometric time of the occultation, velocity component of the moon in the direction of occultation, Signal level, background level and the UD angular diameter. A χ^2 minimisation technique is followed to obtain the best estimation of the five parameters. The point source Fresnel diffraction pattern modulated by the finite telescope aperture, finite optical and electrical bandwidth of the system along with UD angular diameter are used to model the observed light curve.

In case of the InSb photometer (earlier system) faster sampling (upto 1 millisec) is possible for brighter sources ($K \leq 3$) but the system time response has to be taken into account explicitly in the analysis. In case of the subarray operation the sampling time includes integration time, reset time and electronics overheads which are kept to a minimum with a small array size. Typically for an integration and

Table 2. Observed Source details

Source IRC No.	Source Name	Spectral Type	Variability Type	K -mag	V-mag		$(K - [12])$ colour excess	Period (days)	Ref. cat.
+30123	AW Aur	M5-M9	Mira	2.34 ± 0.07	10.10	17.10	1.1	445 ± 10	GCVS
+30136	BS Aur	M8-M9	Mira	2.15 ± 0.06	10.20	> 15.00	2.6	467 ± 05	GCVS
+20116	GP Tau	M7	SRb	0.29 ± 0.07	9.57	10.40	0.9	109 ± 10	ASAS
-20596	RS Cap	M6/M7	SRb	-0.39 ± 0.04	7.90	8.36	1.2	193 ± 15	ASAS
-20585	RT Cap	C	SRb	0.55 ± 0.06	7.66	8.61	0.2	389 ± 10	ASAS

reset time of 3 millisecc each, the sampling time between consecutive subframes is 8.75 millisecc. Compared to single element detector sampling is coarser but higher Signal to Noise is possible on the light curve. Point source LO light curves obtained by the two modes of operation are shown in Fig.1 along with fitted model curves. Insets in the figure show error curves indicating the level of angular resolution achievable. Typically the limiting resolution of the technique with subarrays is about 3 milliarcsec though single element detector operation can do slightly better for bright sources ($K \leq 3$).

3 SOURCE DETAILS

The individual source details are listed in Table 2. and discussed below. UD angular diameters derived from our observations are given for each of the sources and also listed in Table.3.

3.1 AW Aur

AW Aur is a oxygen-rich Mira variable with spectral type ranging from M5 to M9. According to GCVS the reported period is 443.2 days with the epoch of maximum light at JD 2453823.0. The V-band magnitude variation is from 10.10 to 17.10 and Spectral type variation from M5 to M9. Using Lomb-Scargle normalized periodogram formula (Scargle, 1982) we verified that the maximum power in the light curve is at the period of $445(\pm 10)$ days in good agreement with the reported GCVS value. We adopt this value of periodic variability for AW Aur in this paper.

No Hipparcos parallax measurement is available for this source. However, we can make an estimation of the distance to the source using the Period-Luminosity (PL) relation for Galactic Miras as given by Whitelock, Feast & van Leeuwen (2008). We obtain an absolute K-magnitude value -8.18 ± 0.28 and the distance to the source 1.02 ± 0.11 kpc (without extinction correction). This value is in agreement with the value of 1063 pc reported by Le Bertre et al. (2003) who also reported a mass loss rate of $3 \times 10^{-7} M_{\odot} \text{ yr}^{-1}$ for this star. We adopt a value of 1 kpc as distance to the source.

The occultation of AW Aur was recorded close to the maximum (phase 0.95) using the InSb photometer. Following the NLS procedure outlined earlier the observed light curve is fitted with the Uniform Disk (UD) model, which is shown in Fig.2 along with the residuals (data-model) in the lower panel. Inset in the figure shows the error curve for different UD sizes. The minima of this curve indicates our best estimate for the UD angular diameter. For AW Aur we

derive UD angular size of 4.33 ± 0.50 milliarcsec. There is no previous measurement of angular size of this source.

3.2 BS Aur

BS Aur is a late M-type (M8-M9) oxygen-rich Mira variable with a pulsation period of 466.7 days as reported by GCVS. The V-band magnitude varies from 10.20 to > 15.00 with the epoch of maximum light at 2441255.0 JD. Following a similar procedure as in the case of AW Aur we find the maximum power refers to the period $480(\pm 5)$ days which is close to the value reported in the catalog. Using the PL relation as in the case of AW Aur we calculate the absolute K -mag of the source as -8.27 ± 0.20 and estimate a distance of 1.2 kpc (without extinction correction). The LO light curve observed in *NIR K*-band from Mt. Abu using single channel photometer under good sky conditions is shown in Fig.2. The derived UD angular diameter of the source is 5.00 ± 0.70 mas at the photometric phase of 0.83.

3.3 GP Tau

GP Tau is a M7-type giant. According to ASAS catalogue it is a semi-regular (SRb) variable with a period of 109 days and a visual magnitude amplitude of 0.83 (Pojmanski et al., 2005). It is known from IRAS measurements (Helou & Walker, 1986) that GP Tau has a thin circumstellar shell (Sloan & Price (1998). H_2O maser has also been reported in the source (Han et.al 1998; Kim J et.al 2010) at a distance of 10-20 stellar radius from the centre.

The only parallax measurement of GP Tau reported has very large error 10.80 ± 38.30 mas (Hipparcos & Tycho Cat.). No previous angular size measurement is available on this source. Our observed lunar occultation light curve along with its best fit is shown in Fig.3. We obtain the UD angular diameter (θ_{UD}) = 4.85 ± 0.50 mas. We estimate the distance to the source to be ~ 270 pc, using the absolute magnitude ($K = -9.04$) for M7 giants as reported by Wainscoat et al. (1992)

3.4 RS Cap

RS Cap is a late M-type source with a spectral type M6-M7III. It is a semi-regular (SRb) variable. According to the catalog of variable stars in the southern hemisphere (Pojmanski et al., 2005) the period of the source is 193 days with a V-amplitude 0.46 mag. Kahane & Jura (1994) using mm wave observations estimated distance to RS Cap of 280 parsecs. Winters et.al (2003) from *CO* observations report a distance of 277 parsecs and a mass loss rate of

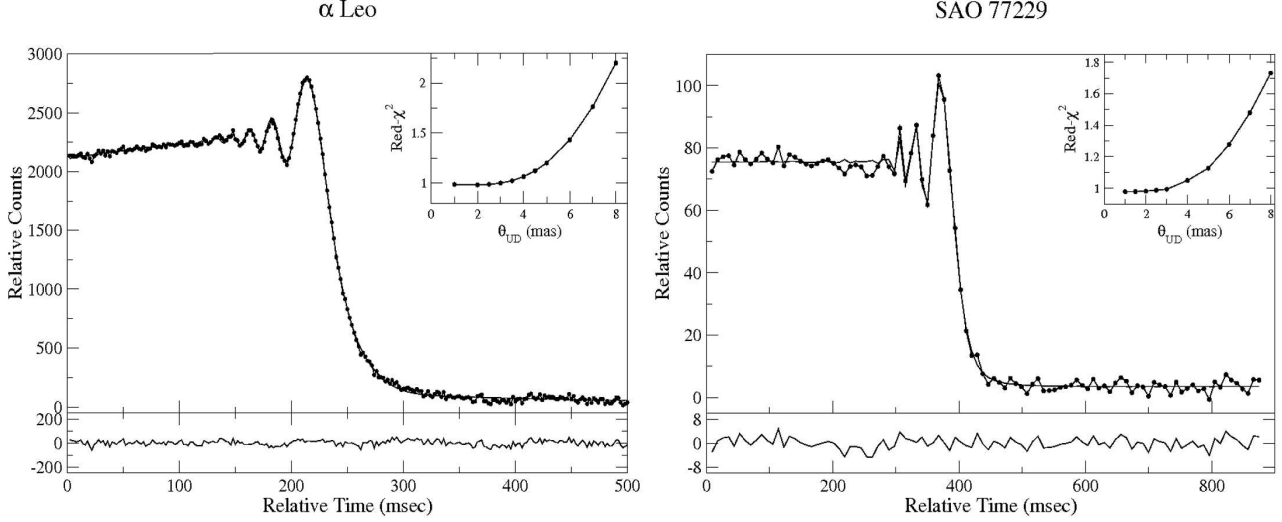


Figure 1. Observed and model fitted light curves of point sources observed by the two different detector systems. The inset shows the error curve of the UD angular diameter determination and the lower panel shows the residuals (data-model) of the best fit. The S/N for α -Leo ($K = 1.6$) light curve is ~ 100 and the same for SAO 77229 ($K = 3.9$) is ~ 40 . The limit of resolution in both the cases is ~ 3 mas.

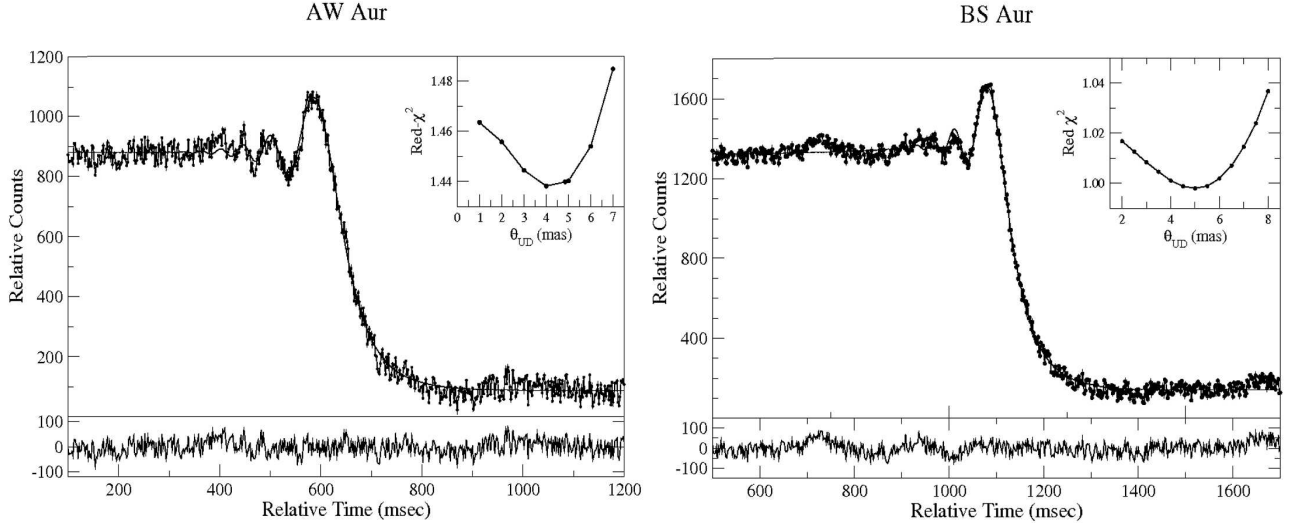


Figure 2. Observed and model fitted light curves of two Mira variables, AW Aur and BS Aur. The inset shows the error curve of the UD angular diameter determination and the lower panel shows the residuals (data-model) of the best fit. Both Miras have been observed in broad K -band.

$\dot{M} = 1.08 \times 10^{-6} M_{\odot} / \text{yr}$. Earlier angular diameter measurements of RS Cap are also available. Richichi et al. (1992) obtained from LO methods the UD angular diameter value of 7.75 ± 0.67 mas and derived the effective temperature of the source to be $T_e = 3560$ K. No circumstellar shell was detected, though the spectral energy distribution indicates the presence of a weak shell around the source with less than 1% strength of the stellar signal. Later Dyck, van Belle & Thompson (1998) reported from interferometric observations at $2.2 \mu\text{m}$ an angular diameter of 7.0 ± 0.8 mas.

We obtain the best fit UD angular diameter of 7.70 ± 0.50 mas which is consistent with earlier measurements. We adopt a distance to the source of 280 pc.

3.5 RT Cap

According to Bergeat & Chevallier (2005) RT Cap is a carbon-rich, non-Mira giant with photospheric carbon to oxygen ratio (C/O) 1.10. The periods derived from V -band light curves are 393 days (GCVS) and 389 days (Pojmanski et al. 2005). The distance to the source is estimated to be 560 pc using apparent and absolute bolometric magnitudes 3.80 and -4.95 respectively (Bergeat, Knapik & Rutily, 2002). They also derived an effective temperature $T_e = 2480$ K and a mass-loss rate of $2.3 \times 10^{-7} M_{\odot} \text{yr}^{-1}$.

There are two high angular diameter measurements reported for this source earlier. One earlier measurement by Schmidtke et al. (1986) using the Lunar Occultation technique in narrow K -band ($2.173 \mu\text{m}/\text{BW } 0.032 \mu\text{m}$) yielded a value of $\theta_{UD} = 7.72 \pm 0.16$ mas at a photometric phase

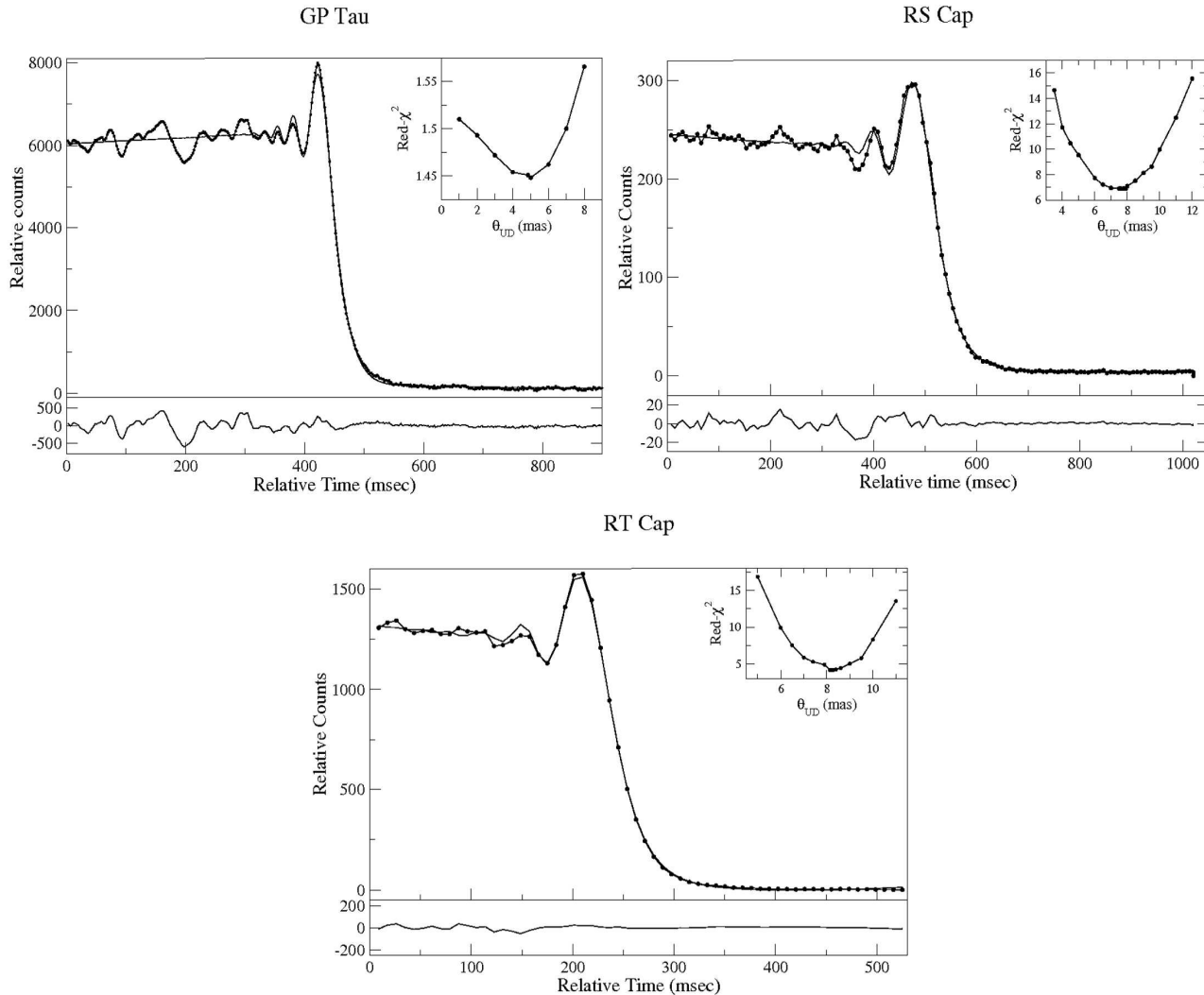


Figure 3. Observed and model fitted light curves of three Semi-regular variables, GP Tau, RS Cap and RT Cap. The inset shows the error curve of the UD angular diameter determination and the lower panel shows the residuals (data-model) of the best fit. While GP Tau and RT Cap are observed in the broad K -band, RS Cap measurements are in a narrow band ($2.37 \mu\text{m} / 0.1 \mu\text{m}$).

of 0.98. Another value reported using long-baseline interferometry in broad K -band (van Belle et al., 2000) is $\theta_{UD} = 8.18 \pm 0.21$ mas.

From our observed light curve (Fig.3) we derive a UD value of $\theta_{UD} = 8.14 \pm 0.50$ mas at a photometric phase of 0.72.

4 RESULTS AND DISCUSSIONS

Uniform disk (UD) Angular diameters of the five sources derived from our observations and analysis are listed in second column of Table.3.

4.1 UD Angular Diameter predictions using $(V - K)$ colour

We have first made an attempt to compare our results with the predictions of angular sizes generated by us following the approximate methods devised by Di Benedetto (1993) and van Belle (1999). The methods use the observed K and V

broad band photometry to predict a zero magnitude ($V = 0$) angular size using $(V - K)$ values through a calibration. The zero magnitude angular sizes are then scaled to the apparent angular sizes using V -band photometry. We have generated a new calibration using the 54 measured K -band angular diameter determinations of oxygen-rich Miras available in the literature (Richichi et al., 2005), scaled to the zero-magnitude angular diameters, and plotted against their respective $(V - K)$ values (Fig.4). We have also derived a similar relationship for SRVs using 83 sources from the same catalog (Fig.4). A good correlation is obtained in both cases (correlation coefficients of 0.94 (Miras) and 0.98 (SRVs)). It must be pointed out that the errors involved in the angular diameter predictions by these methods is in the range 20 to 25 % due to difficulties of obtaining contemporaneous photometry. Nevertheless the method outlined appears to have a good predictive value for angular diameters using only $(V - K)$ colour for both Miras and SRVs.

The predicted UD angular diameters for our 5 sources are listed in third column of Table.3. It is seen that there is a good agreement in general between our measured values

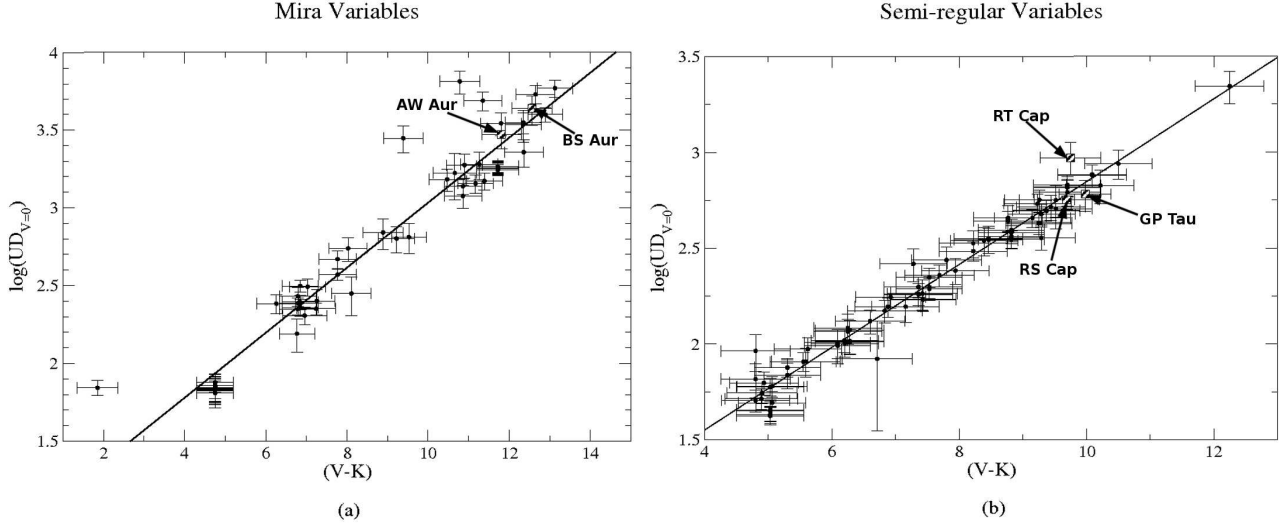


Figure 4. The $(V-K)$ colour vs. zero-magnitude angular diameter of o -rich Mira variables (54 measurements) (a) and SRVs (83 measurements) (b). The solid line represents the least squares fit to these points. [correlation coefficients are 0.94 (Miras) and 0.98 (SRVs)]. Position of sources in our sample is also indicated. Please note that RS Cap measurements are in narrow band filter ($2.37\mu\text{m}/0.1\mu\text{m}$).

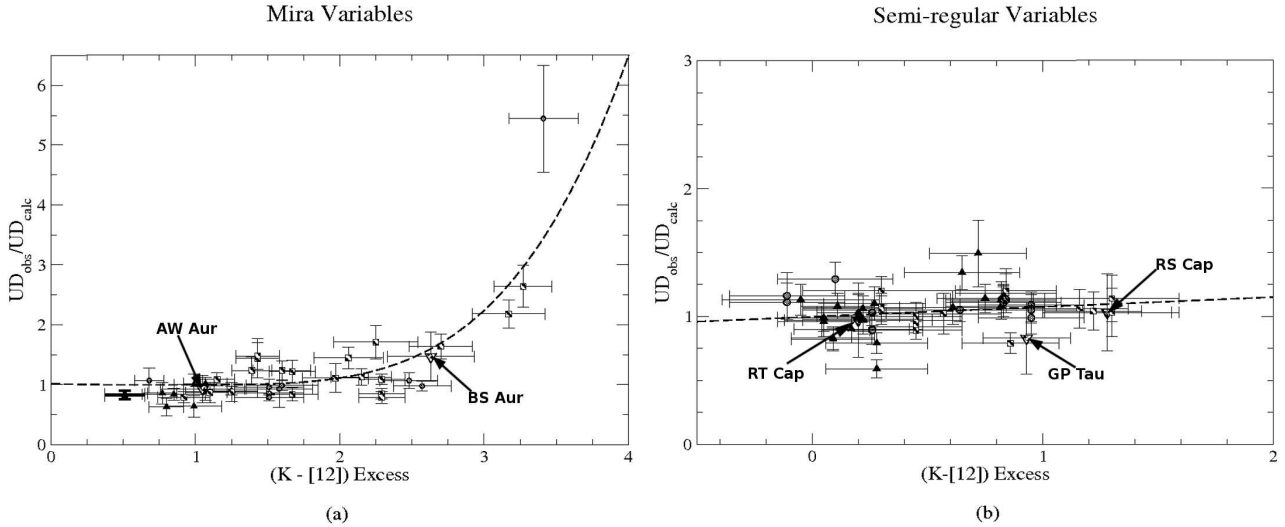


Figure 5. The $(K - [12])$ colour excess vs. the ratio of observed and calculated angular diameters for both Mira variables (a) and Semi-regular variables (b) as described in the text. The dotted lines show a polynomial through the points to indicate the rising trend. Our observed sources are also plotted and labelled. Please note that RS Cap measurements are in narrow band filter ($2.37\mu\text{m}/0.1\mu\text{m}$).

and predictions. However, in case of RT Cap the prediction gives a lower value. It must be pointed out that RT Cap is a carbon rich semi-regular variable, and so it cannot be readily compared with generally oxygen rich SRVs used in the calibration curve.

4.2 Enhancement of Angular diameter due to Mass loss/shell effects in Miras

In the case of the two Miras in our sample we have also investigated the possibility of high mass loss rates and presence of a circumstellar shell affecting the angular size measurements. This aspect of enhancement of UD angular size due to mass loss was discussed earlier by van Belle, Thompson & Creech-Eakman (2002). These authors had derived, for a

sample of Miras, the ratio of linear radius (obtained from angular size measurements and distance estimates) to the theoretical (Rosseland) radius assuming that Miras are all fundamental mode pulsators. A plot of this ratio as a function of $(K - [12])$ colour excess which is indicative of mass loss showed that Miras with higher colour excess were systematically $120 R_{\odot}$ larger than their counterparts with lower colour excess, independent of the periods.

We have adopted a slightly different approach using a sample of 43 oxygen rich Miras with spectral types later than M5. In order to avoid the large errors involved in distance measurements we plot the ratio of observed and calculated angular diameters against $(K - [12])$ colour excess. The K -band magnitudes and $12\mu\text{m}$ fluxes are collected from 2MASS catalog (Cutri et al., 2003) and IRAS catalog (Helou

& Walker, 1986) respectively. The calculated angular diameter is derived from bolometric flux and effective temperature, and is also independent of distance. The bolometric fluxes are calculated using the mean relation between bolometric flux, K -band flux and $(V - K)$ colour as reported by Dyck, Lockwood & Capps (1974) and the corresponding effective temperatures are collected from Alvarez & Mennessier (1997). The ratio of reported UD angular diameters (Richichi et al., 2005) and calculated angular diameters (UD_{calc}) are then plotted against the $(K - [12])$ colour excess (Fig. 5a). The plot shows that the ratio remains close to unity upto a colour excess ~ 2.5 , and then increases sharply. For a colour excess of ~ 3 the measured UD diameter is almost twice the calculated value. The measured UD diameter of AW Aur is in good agreement with the calculated value showing a ratio ~ 1 . However the observed value of BS Aur is almost 1.4 times the calculated value (Table.3, column 4). We have also plotted the positions of our sources (AW Aur and BS Aur) in Fig. 5a which suggests that BS Aur has a high mass loss rate and may harbour a shell. This is also borne out by the IRAS LRS characterization of these two stars. According to this characterization, AW Aur (LRS Char 15) does not have any detectable circumstellar shell but BS Aur (LRS Char 28) has a thin o -rich shell around it.

Following the above procedure we have also carried out a similar investigation for SRVs using a sample of 52 K -band angular diameter measurements (later than M5) taken from Charm2 catalog (Richichi et al., 2005). The SRVs in the sample have a $(K - [12])$ colour excess less than 1.5 (unlike Miras) and the ratio close to unity (Fig. 5b). It appears unlikely that SRVs may exhibit enhancement in their angular diameter.

Using the available distance estimates of each of these sources given in section 3 we have derived, using our measured UD angular diameters the linear radii of the sources corrected for enhancement. With a reduction of 40% of the enhanced size of BS Aur we find that both Miras have a similar radii (Table.3, column 5). However, it may be pointed out that due to large unknown errors in distance to these sources the absolute errors involved in linear radii could be much higher. Hence it is difficult to draw any conclusion regarding the mode of pulsation of these two Miras.

It is speculated that SRVs can pulsate in a number of modes and that too often simultaneously (Lattanzio & Wood, 2003). However, in the absence of reliable distance measurements it is difficult to draw definitive conclusions from our angular diameter measurements.

5 CONCLUSIONS

K -band uniform disk angular diameters of two Mira variables and three Semi-regular variables (SRVs) are reported. For the two Miras and one SRV (GP Tau) these are the first time angular diameter measurements. For the other two SRVs our values are in good agreement with those reported earlier. Two separate comparative studies have been made to examine our measured values with predictions. One of the methods involves a separate calibrations for Miras and SRVs with previously reported K -band diameters and $(V - K)$ colours. In this case we find a good agreement between measurements and predictions except for one SRV

Table 3. Results.

Source	Obs. θ_{UD} (mas)	Pred. θ_{UD} (mas)	Ratio $\frac{UD_{obs}}{UD_{calc}}$	Linear Radius (Corrected) (R_{\odot})
AW Aur	4.33 \pm 0.50	4.0 \pm 1.0	1.1 \pm 0.1	440 \pm 100
BS Aur	5.00 \pm 0.70	4.5 \pm 1.2	1.4 \pm 0.2	470 \pm 110
GP Tau	4.85 \pm 0.50	6.1 \pm 1.5	0.8 \pm 0.1	175 \pm 40
RS Cap*	7.70 \pm 0.50	8.3 \pm 2.1	1.0 \pm 0.1	230 \pm 40
RT Cap	8.14 \pm 0.30	5.4 \pm 1.3	1.0 \pm 0.1	490 \pm 70

* RS Cap has been observed in narrow CO -band filter ($2.37\mu m$ / $0.1\mu m$).

(RT Cap) which is a carbon star. We have also investigated the enhancement of measured UD angular diameter due to heavy mass loss and the presence of a circumstellar shell as indicated by $(K - [12])$ colour excess. We find AW Aur is unlikely to harbour a shell. But for the other Mira in our sample (BS Aur) UD angular diameter measured appears enhanced by nearly 40% compared to the expected value due to presence of a circumstellar shell arising out of mass loss.

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